

MANUAL OF AIRCRAFT GROUND DE-ICING/ANTI-ICING OPERATIONS

SECOND EDITION — 2000



*Approved by the Secretary General
and published under his authority*

INTERNATIONAL CIVIL AVIATION ORGANIZATION

Manual of Aircraft Ground De-icing/Anti-icing Operations

(Doc 9640-AN/940)

SECOND EDITION — 2000



AMENDMENTS

Amendments are announced in the supplements to the *Catalogue of ICAO Publications*; the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

[illegible][illegible]
$$(i\dot{i})$$

Foreword

Safe aeroplane operations during all types of weather conditions are of utmost concern to all air carriers, airport authorities, air traffic control, and users of air transport services. A review of the history of aeroplane accidents in the air transportation industry revealed that a substantial number are related to winter operations. An examination of these accidents showed a need for formally developed regulations and procedures governing aeroplane de-icing/anti-icing operations, directed towards all segments of aviation, including aeroplane manufacturers, airline operators, and engineering, maintenance and service organizations. This material was intended, in particular, for use by flight crews of all aeroplane types and categories, as well as aeroplane maintenance and service personnel.

The International Air Transport Association (IATA) convened a Global De-icing/Anti-icing Task Force, which met for the first time in Helsinki in September 1992. In October 1993, this Task Force became the IATA Global De-icing/Anti-icing Industry Forum. In a cooperative effort between IATA and ICAO, a drafting group was formed to develop a “stand-alone” ground de-icing/anti-icing document, which would be published by ICAO. The meetings, convened throughout the year for the purpose of developing this document, were attended by representatives of civil aviation authorities, airline operators, aeroplane manufacturers, ground equipment and fluid manufacturers, pilot associations and airport authorities. The result was the publication of the first edition of the *Manual of Aircraft Ground De/Anti-icing Operations* (Doc 9640) in 1995.

This second edition comprises a summary of information essential to the planning and execution of de-icing/anti-icing operations during conditions which are conducive to aeroplane icing on the ground. It contains general information which is intended to increase the basic understanding of aircraft ground de-icing/anti-icing operations and to facilitate the development of standardized procedures and guidance material for the various segments of the aviation industry. It includes the full range of de-icing/anti-icing fluids and information on data updating. A general description of the various factors relating to aeroplane icing on the ground is provided, and the minimum procedural requirements necessary to conduct safe and efficient operations during conditions requiring aeroplane de-icing/anti-icing activities are addressed. It is the individual operator's responsibility, however, to comply with the requirements imposed by aeroplane, equipment and fluid manufacturers, regulatory and environmental authorities, and individual operator programmes.

Reference material used to prepare this publication includes documentation from regulatory authorities, airlines, aeroplane manufacturers, equipment and fluid manufacturers, industry, and academic, standardization and professional associations (see Bibliography for complete listing). Even though no reference is made in this document to any specific instructions or recommendations given by aeroplane, equipment or fluid manufacturers, nevertheless these must also be taken into consideration.

Table of Contents

	<i>Page</i>		<i>Page</i>
Glossary of terms and abbreviations	1	Chapter 9. Air traffic control (ATC) winter operations plan	15
Chapter 1. Introduction	3	Chapter 10. De-icing/anti-icing communications . .	16
Chapter 2. The Clean Aircraft Concept	5	Chapter 11. De-icing/anti-icing methods	17
Chapter 3. Aeroplane icing on the ground	6	Chapter 12. Ice detection and warning systems . . .	18
Chapter 4. Aeroplane ground de-icing/anti-icing fluids	7	Chapter 13. Training of personnel	19
Chapter 5. Holdover times	9	Chapter 14. Equipment	20
Chapter 6. De-icing/anti-icing check procedures	10	Chapter 15. Quality assurance programme	22
Chapter 7. Responsibilities	11	Chapter 16. Updating of holdover time guidelines and de-icing/anti-icing procedures	23
Chapter 8. Aerodrome de-icing/anti-icing facilities	12	Attachment	25
		Bibliography	31

Copyright International Civil Aviation Organization
Provided by IHS under license with ICAO
No reproduction or networking permitted without license from IHS
Full document details: ICAO 9640 2000

Glossary of Terms and Abbreviations

GLOSSARY OF TERMS

These terms, as used in this document, have the following meanings:

Active frost. A condition when frost is forming. Active frost occurs when the surface temperature is at or below 0°C and at or below the dew point.

Anti-icing. Anti-icing is a precautionary procedure by which clean aeroplane surfaces are protected against the formation of ice and frost and the accumulation of snow and slush for a limited period of time.

Cold-soak effect. The wings of aeroplanes are said to be “cold-soaked” when they contain very cold fuel as a result of having just landed after a flight at high altitude or from having been refuelled with very cold fuel. Whenever precipitation falls on a cold-soaked aeroplane when on the ground, clear icing may occur. Even in ambient temperatures between –2°C and +15°C, ice or frost can form in the presence of visible moisture or high humidity if the aeroplane structure remains at 0°C or below. Clear ice is very difficult to detect visually and may break loose during or after take-off. The following factors contribute to cold-soaking: temperature and quantity of fuel in fuel cells, type and location of fuel cells, length of time at high altitude, temperature of refuelled fuel and time since refuelling.

Critical surfaces. Surfaces of the aeroplane that shall be completely free of ice, snow, slush or frost before take-off. The critical surfaces shall be determined by the aeroplane manufacturer.

De-icing. The process which removes ice, snow, slush or frost from aeroplane surfaces. This may be accomplished by mechanical methods, or by pneumatic methods or through the use of heated fluids. Mechanical methods may be preferred under extremely cold conditions or when it has been determined that the frozen contaminant is not adhering to the aeroplane surfaces. When using heated fluids and optimum heat transfer is desired, fluids should be applied at a distance from the aeroplane surfaces in accordance with the approved operator procedure and fluid manufacturer recommendations.

De-icing/anti-icing. A procedure combining both the de-icing process and the anti-icing process and which can be performed in one or two steps:

One-step de-icing/anti-icing. This procedure is carried out with heated anti-icing fluid. The fluid is used to de-ice the aeroplane and remains on the aeroplane surface to provide anti-icing capability. The Society of Automotive Engineers (SAE)/International Organization for Standardization (ISO) Type I, II, III and IV fluids can be used, but the protection provided by Type I fluid is less than that provided by Type II, III and IV fluids.

Two-step de-icing/anti-icing. This procedure contains two distinct steps. The first step, de-icing, is followed by the second step, anti-icing, as a separate fluid application. After de-icing, a separate overspray of anti-icing fluid is applied to protect the aeroplane’s critical surfaces, thus providing maximum anti-icing protection.

Drizzle. Fairly uniform precipitation composed exclusively of fine drops (diameter less than 0.5 mm (0.02 in)) very close together. Drizzle appears to float while following air currents although, unlike fog droplets, drizzle falls to the ground.

Fog and ground fog. A visible aggregate of minute water particles (droplets) in the air reducing the horizontal visibility at the Earth’s surface to less than 1 kilometre.

Freezing fog. A fog formed of supercooled water droplets which freeze upon contact with exposed objects and form a coating of rime/clear ice.

Freezing rain and freezing drizzle. Rain or drizzle in the form of supercooled water drops which freeze upon impact with any surface.

Frost. Referred to as “hoar frost”. A deposit of ice having a crystalline appearance, generally assuming the form of scales, needles or fans. Frost is formed by sublimation, i.e. when water vapour is deposited upon a surface whose temperature is at or below freezing.

High humidity. An atmospheric condition where the relative humidity is close to saturation.

Holdover time. Holdover time (HOT) is the *estimated* time the anti-icing fluid will prevent the formation of ice and frost and the accumulation of snow on the protected (treated) surfaces of an aeroplane.

Precipitation intensity. Intensity of precipitation is an indication of the amount of precipitation collected per unit time interval. It is expressed as light, moderate or heavy. Intensity is defined with respect to the type of precipitation occurring, based either on rate of fall for rain and ice pellets or visibility for snow and drizzle. The rate of fall criterion is based on time and does not accurately describe the intensity at a particular time of observation.

Rain. Precipitation of liquid water particles, either in the form of drops of more than 0.5 mm in diameter or smaller drops which, in contrast to drizzle, are widely separated.

Rime. A deposit of ice, produced by freezing of super-cooled fog or cloud droplets on objects at temperatures below or slightly above freezing. It is composed of grains separated by air, sometimes adorned with crystalline branches.

Shear force. Shear force is a force applied laterally on an anti-icing fluid. When applied to a Type II, III or IV fluid, the shear force will reduce the viscosity of the fluid; when the shear force is no longer applied, the anti-icing fluid should recover its viscosity. For instance, shear forces are applied whenever the fluid is pumped, forced through an orifice or when subjected to airflow. If excessive shear force is applied, the thickener system could be permanently degraded and the fluid viscosity may fall outside the range set by the manufacturer and tested for certification. Fluid degraded in this manner should not be used for operational purposes.

Slush. Water-saturated snow which with a heel-and-toe slap-down motion against the ground will be displaced with a splatter.

Snow. Precipitation of ice crystals, mostly branched in the form of six-pointed stars. The crystals are isolated or agglomerated to form snowflakes.

Dry snow. When the ambient temperature is below freezing.

Wet snow. When the ambient temperature is near or above freezing.

Visible moisture. Fog, rain, snow, sleet, high humidity (condensation on surfaces), ice crystals can all produce visible moisture on aeroplanes, taxiways and runways exposed to and contaminated by these conditions.

ABBREVIATIONS

AEA	Association of European Airlines
APU	Auxiliary power-unit
ATC	Air traffic control
DIN	Deutsches Institut für Normung
FP	Freezing point
FPD	Freezing point depressant
ISO	International Organization for Standardization
OAT	Outside air temperature
SAE	Society of Automotive Engineers

Chapter 1

INTRODUCTION

1.1 As early as 1950, some States had established civil aviation regulations prohibiting take-off for aeroplanes with frost, snow, or ice adhering to wings, propellers or control surfaces of the aeroplane. The effects of such icing are wide-ranging, unpredictable and dependent upon individual aeroplane design. The magnitude of these effects is dependent upon many variables, but the effects can be both significant and dangerous.

1.2 Wind tunnel and flight tests indicate that ice, frost or snow formations on the leading edge and upper surface of a wing, having a thickness and surface roughness similar to medium or coarse sandpaper, can reduce wing lift by as much as 30 per cent and increase drag by up to 40 per cent. These changes in lift and drag will significantly increase stall speed, reduce controllability and alter aeroplane flight characteristics. Thicker or rough ice accumulation in the form of frost, snow, or ice deposits can have increasing effects on lift, drag, stall speed, stability and control, but the primary influence is surface roughness relative to critical portions of an aerodynamic surface. Ice on critical surfaces and on the airframe may also break away during take-off and be ingested into engines, possibly damaging fan and compressor blades. Ice forming on pitot tubes and static ports or on angle of attack vanes may give false attitude, airspeed, angle of attack and engine power information for air data systems. It is therefore imperative that take-off not be attempted unless it has been ascertained that all critical surfaces of the aeroplane, as well as all instrument probes, are free of adhering snow, frost or other ice formations. This vital requirement is known as the “Clean Aircraft Concept” (see Chapter 2).

1.3 Most aeroplanes used in commercial air transport operations, as well as some other aeroplane types, are certificated for flight in icing conditions. Aeroplanes so certificated were designed to have the capability to penetrate supercooled cloud icing conditions and have demonstrated this in flight. This capability is provided either by ice protection equipment installed on critical surfaces, such as the leading edge, or by demonstration that the ice formed, under supercooled cloud icing conditions, on certain unprotected components will not significantly affect aeroplane performance, stability and control. Ice,

frost and snow formed on these surfaces on the ground can have a totally different effect on aeroplane flight characteristics than ice formed in flight. Exposure on the ground to weather conditions that are conducive to ice formation can cause accumulation of frost, snow or ice on areas of the aeroplane where the ice protection provided is designed for in-flight use only. In addition, aeroplanes are considered airworthy and are certificated only after extensive analyses and testing have been accomplished. With the exception of analyses and testing to ascertain the flight characteristics of an aeroplane during flight in icing conditions, all analyses and certification testing are conducted with a clean aeroplane flying in a clean environment. If ice formations other than those considered in the certification process are present, the airworthiness of the aeroplane may be invalid and no attempt should be made to fly the aeroplane until it has been restored to the clean configuration.

1.4 Common practice developed by the aviation industry over many years of operational experience is to de-ice/anti-ice an aeroplane prior to take-off. Various techniques for ground de-icing/anti-icing aeroplanes were also developed. The most common of these techniques is the use of FPD fluids to aid the ground de-icing/anti-icing process and to provide a protective anti-icing film to delay the formation of frost, snow or ice on aircraft surfaces.

1.5 In scheduled airline operations where large numbers of aeroplanes are dispatched, the process of ensuring airworthiness must be a team effort where each member of the team has specific duties and responsibilities (Annex 6, Part I, refers). In private aeroplane operations, all functions may be performed by only one person — the pilot. In all cases, the pilot-in-command has the ultimate responsibility of ascertaining that the aeroplane is safe for flight.

1.6 The only known method for positively ascertaining that an aeroplane is clean prior to take-off is by close inspection. Under conditions of precipitation or fog, or where moisture can be splashed, blown or sublimated onto critical surfaces in sub-freezing weather, many factors influence whether and how much ice, frost or snow may

accumulate and result in surface roughness. Even in above-freezing weather conditions, for aeroplanes which have just landed after descending from high altitude or have refuelled with very cold fuel, the wings may be colder than 0°C due to fuel in the wing tanks being well below zero. This cold-soak effect may cause ice to form on the wing surfaces. Most of the factors that influence the accumulation of freezing precipitation and affect cold-soak are listed below:

- a) ambient temperature;
- b) relative humidity;
- c) precipitation type and rate;
- d) fog type and density;
- e) heat radiation;
- f) wind speed and direction;
- g) aeroplane surface temperature (including the temperature of fuel in the wing tanks);
- h) presence of de-icing fluid;
- i) de-icing/anti-icing fluid type and temperature;
- j) de-icing/anti-icing fluid aqueous solution (strength);
- k) de-icing/anti-icing fluid application procedure;
- l) time elapsed since anti-icing treatment;

- m) operation in close proximity to other aeroplane jet blast, equipment and structures;
- n) operations on snow, slush or wet surfaces;
- o) aeroplane component inclination angle, contour and surface roughness; and
- p) conditions under which the aeroplane is parked (outside, or fully or partially in the hangar).

1.7 Personnel must understand and have a thorough knowledge of:

- a) the adverse effects that ice, frost or snow on the critical surfaces and airframe can have on aeroplane performance and handling qualities;
- b) the various procedures that are available for aeroplane ground de-icing/anti-icing;
- c) the capabilities and limitations of these procedures;
- d) the variables that will influence the effectiveness of these procedures; and
- e) the critical areas of the particular aeroplane.

It is essential for all personnel to recognize that final assurance for a safe take-off rests in a thorough pre-take-off inspection or check.

Chapter 2

THE CLEAN AIRCRAFT CONCEPT

2.1 During conditions conducive to aeroplane icing during ground operations, take-off shall not be attempted when ice, snow, slush or frost is present or adhering to the wings, propellers, control surfaces, engine inlets or other critical surfaces. This is known as the “Clean Aircraft Concept”. In this document, the Clean Aircraft Concept deals solely with fixed wing aeroplanes.

2.2 Any deposit of ice, snow or frost on the external surfaces of an aeroplane, except as permitted in the flight manual, may drastically affect its performance due to reduced aerodynamic lift and increased drag resulting from the disturbed airflow. Furthermore, slush, freezing snow or ice may cause moving parts, such as control surfaces and flap-actuating mechanisms, to jam, thus creating a hazardous situation. These adverse effects on the aerodynamic properties of the airfoil may result in a sudden departure from the commanded flight path and may not be preceded by any cockpit indications or aerodynamic warnings to the pilot.

2.3 A large number of variables can influence the formation of ice and frost and the accumulation of snow and slush causing surface roughness on an aeroplane. These variables include:

a) ambient temperature;

b) aeroplane skin temperature;

c) precipitation rate and moisture content;

d) de-icing/anti-icing fluid temperature;

e) the fluid/water ratio of the de-icing/anti-icing fluid;

f) relative humidity; and

g) wind velocity and direction.

They can also affect the de-icing capabilities of de-icing fluids and the anti-icing capabilities of anti-icing fluids. As a result, a well-defined time for the protection provided by an anti-icing fluid cannot be established.

2.4 Numerous techniques for complying with the Clean Aircraft Concept have been developed. Proper and adequate de-icing, followed by an application of appropriate anti-icing fluid, provides the best protection against contamination. A visual or physical check of critical aeroplane surfaces to confirm that the treatment has been effective and that the aeroplane is in compliance with the Clean Aircraft Concept must be carried out.

Chapter 3

AEROPLANE ICING ON THE GROUND

3.1 Many atmospheric and ambient conditions can cause aeroplane icing on the ground. The principal conditions are frost, snow, freezing fog, freezing drizzle, freezing rain, and rain, drizzle, fog or high humidity combined with the cold-soak effect. The latter type of icing can occur at ambient temperatures well above the freezing point. It is also important to understand that mixed and changing atmospheric conditions can overlap during aeroplane operations on the ground, requiring constant vigilance by both flight and ground crews. Clear ice or failed anti-icing fluid can be very difficult to identify.

3.2 Other conditions that are conducive to icing contamination on aeroplane surfaces are:

- a) operations on ramps, taxiways and runways contaminated by water, slush or snow. These substances may be deposited on aeroplane surfaces by

wind, aeroplane operations, jet blast, or ground support equipment; and

- b) warm aeroplane surfaces exposed to frozen precipitation during below-freezing conditions. The warm aeroplane surfaces may cause melting and refreezing of the precipitation.

3.3 In many cases, de-icing/anti-icing procedures may be ineffective in providing sufficient protection for continued operations. This can occur when there is freezing rain, freezing drizzle, heavy snow, or any condition where high water content is present in freezing precipitation.

3.4 At very low ambient temperatures (below approximately -30°C), some heated Type I fluids are no longer effective, and other methods of frozen contamination removal must be used.